

FORM PTO-1390 (Modified)
REV 11-2000

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

**TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371**

70991-0408

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

10/069233

INTERNATIONAL APPLICATION NO.

PCT/US00/20790

INTERNATIONAL FILING DATE

23 AUGUST 2000 (23.08.00)

PRIORITY DATE CLAIMED

25 AUGUST 1999 (25.08.99)

TITLE OF INVENTION

DUAL MAST SYSTEM FOR SIMULATION TESTING

APPLICANT(S) FOR DO/EO/US

Xuegeng ZHU

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information.

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ has been communicated by the International Bureau.
 - c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
 - a. ☐ is attached hereto.
 - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
 - b. ☐ have been communicated by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (e)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

DUAL MAST SYSTEM FOR SIMULATION TESTING

TECHNICAL FIELD

This invention relates to the art of simulation testing. In particular, the invention relates to a rig for simulation testing a full exhaust system for an automobile.

BACKGROUND

Durability testing of automotive parts is commonly used to determine the lifetime of the parts. Such testing has been conducted by placing the part to be tested on a "durability automobile" and running that automobile over a test track under prescribed test conditions for a prescribed period of time. That type of testing, however, requires a significant amount of time due to delays in assembling and scheduling the durability automobile and delays caused by downtime attributed to other parts being tested on the same vehicle.

Simulation testing was developed to reduce the time required for durability testing and thus to reduce the overall time required for new product development. reducing some new product cycles from as much as nine months to as little as one month. Simulation testing involves placing a part to be tested on a "rig," which is designed to replicate the motion of a durability vehicle to subject the part under test to that motion without the problems incident to actual operation of the durability vehicle. This is often accomplished by placing sensors at critical places on the durability vehicle and recording the relative motions at those locations. Then, the test rig is designed to replicate those motions as exactly as possible.

A problem with simulation testing is that of correlation. That is, the results obtained by simulation testing must correlate very well with those obtained by durability vehicle testing for the simulation test to replace the durability vehicle test. Design of a test rig to obtain that correlation has not always been successful.

A prior art rig is that known as a MAST (multi-axis simulation table). A known MAST provides motions about six degrees of freedom, namely the three Cartesian directions and roll, pitch and yaw about respective ones of those axes. The motions are provided in prescribed amounts, such as 3.5-7 G's in the translation directions and 0-50 Hz frequency response on all axes. Generally the system is controlled by a computer, and twelve or more input channels from sensors on the equipment being tested are provided.

The prior MAST rig suffers from the limitation that it is generally a rigid table (e.g., 60 inches by 84 inches) that subjects the entire part being tested to the same motions. In the field of automotive testing, however, applicant has discovered that such a rig can not adequately replicate the motion of an extended part, such as an exhaust system, on a vehicle. Thus, the typical MAST rig does not provide adequate correlation.

Applicant has found that one reason for the lack of correlation provided by the known MAST rig when testing an elongate system, such as an exhaust system, is that the chassis of a vehicle flexes, resulting in motions at one part of the chassis that differs significantly from those at the other end. Moreover, the fundamental frequency of a chassis is generally much lower than for other parts of an automobile.

SUMMARY OF THE INVENTION

In accordance with the invention, applicant has discovered that significantly enhanced correlation can be obtained by mounting the part to be tested on multiple rigs, such as MAST's. In the preferred embodiment, two MAST rigs are used, with one part of the system being tested being mounted on one and the remainder of the system on the other. While the multiple systems can be connected, such as by mounting one MAST on another, applicant's preferred embodiment provides two independent MAST rigs whereby the motion of the part on one MAST is not dependent on the motion of another MAST.

For example, when the system to be tested is an exhaust system, which involves an engine with exhaust manifolds, catalytic converters, mufflers, and associated tubing, the engine and manifolds are mounted on a first MAST and the remainder of the system on a second, uncoupled MAST. This is accomplished in the preferred embodiment by providing two MAST's longitudinally arranged on a floor.

Because each of the MAST's can be programmed separately, the motions applied to the engine and the mufflers can differ and can, therefore, come much closer to replicating the actual motion of the various parts of the durability vehicle.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of a dual MAST rig in accordance with the invention.

Figure 2 is a side view of the rig shown in figure 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to the figures, a multiple-MAST full exhaust system simulation rig in accordance with the invention comprises a first MAST rig 2 and a second MAST rig 4 arranged adjacent each other and mounted on a common floor, such as the concrete floor of a test facility. Each of the MAST rigs 2 and 4 is preferably capable of providing motions about six degrees of freedom. Because the rigs are not coupled, they may be controlled separately to accommodate different motions of the different parts of a vehicle for which the exhaust system is designed.

Each MAST includes a table 6 that is mounted for motion about six degrees of freedom. The tables are generally rigid and are connected to a plurality of computer controlled, hydraulic actuators to provide the required motion. Three of the actuators 8 for each table are mounted for horizontal motion, with two parallel and one perpendicular to the others. At least three actuators 10 are provided beneath each of the tables for generating vertical, and pitch and roll motions.

In the preferred embodiment for use in testing an exhaust system, an engine 12 is mounted on a first of the MAST rigs and the tail pipe hangers 14 are mounted to a second of the MAST rigs. By this arrangement the vehicle motions on the engine are separated from those of the tailpipe, resulting in enhanced correlation.

The MAST rigs shown are those manufactured by MTS Systems of Loveland, OH, but the rigs may be of other types. The MAST rigs shown are generally capable of providing motions in the range of 0 to 50 Hz. In a further modification of this arrangement, one of the MAST rigs is replaced with a system that provides motions at higher frequencies, such as that sold under the trademark CUBE, e.g., for mounting the engine.

I claim:

1. A simulation test system comprising a first multi-axis simulation table and a second multi-axis simulation table, wherein the first and second multi-axis simulation tables are arranged to receive separate parts of a system to be tested.
2. A simulation test system according to claim 1 wherein said first and second multi-axis simulation tables are uncoupled.
3. A method for simulation testing comprising providing first and second multi-axis simulation rigs, mounting a first part of a system to be tested to said first multi-axis simulation rig and mounting a second part of said system to be tested on said second multi-axis simulation rig.
4. A method according to claim 3 wherein said first and second multi-axis simulation rigs are uncoupled.
5. The simulation test system of claim 1, wherein each multi-task simulation table has at least six degrees of movement.
6. The simulation test system of claim 1, wherein each multi-axis simulation table has a plurality of actuators for moving each of the tables, the actuators for one table being independent of the actuators of the other table so that movement imparted by actuators to one table can vary from movement imparted by actuators to the other table.
7. The simulation test system of claim 6, wherein each of the plurality of actuators is hydraulically driven.
8. The simulation test system of claim 1, wherein a first plurality of actuators are arranged to provide a generally horizontal motion and a second plurality of actuators are arranged to provide a generally vertical motion to each multi-axis simulation table.

9. The simulation test system of claim 9, wherein the first plurality of actuators include two actuators that are aligned to impart a parallel generally horizontal motion, and one actuator positioned impart a generally horizontal motion perpendicular to the parallel motion imparted by the two actuators.

10. The simulation test system of claim 1, further including an exhaust system comprising an engine supported by one of the multi-task simulation tables, at least one exhaust pipe extending from the engine, and at least one exhaust pipe hanger supported by the other multi-task simulation table.

11. The simulation test system of claim 10, comprising a pair of exhaust pipes, and a pair of exhaust pipe hangers.

12. The method of claim 3, comprising subjecting each rig to movement through a plurality of actuators for durability testing of the system.

13. The method of claim 12, wherein each actuator is hydraulically driven.

14. The method of claim 3, wherein each rig is subjected to generally horizontal and generally vertical forces as part of said movement.

15. The method of claim 14, wherein generally horizontal forces are applied in two directions, one direction generally perpendicular to the other direction.

16. The method of claim 3, comprising durability testing an exhaust system by mounting an engine of the exhaust system to one of the rigs and at least one exhaust pipe of the exhaust system to the other of the rigs.

17. The method of claim 3, wherein each of the rigs is capable of movement in six degrees of freedom.

18. The method of claim 3, wherein one rig is subjected to one set of movements and the other rig is subjected to another and different set of the movements for the simulation testing.

19. The method of claim 15, comprising durability testing an exhaust system by mounting an engine of the exhaust system to one of the rigs and at least one exhaust pipe of the exhaust system to the other of the rigs.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
1 March 2001 (01.03.2001)

PCT

(10) International Publication Number
WO 01/14845 A1

(51) International Patent Classification: G01M 17/00

(21) International Application Number: PCT/US00/20790

(22) International Filing Date: 23 August 2000 (23.08.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/150,532 25 August 1999 (25.08.1999) US

(71) Applicant (for all designated States except US): AP AUTOMOTIVE SYSTEMS, INC. [US/US]; 315 Matzinger Road, Toledo, OH 43612 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): ZHU, Xuegeng [US/US]; 3150 Middlesex Drive, Toledo, OH (US).

(74) Agents: BRODY, Christopher, W. et al.; Clark & Brody, Suite 600, 1750 K Street, NW, Washington, DC 20006 (US).

(81) Designated States (national): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

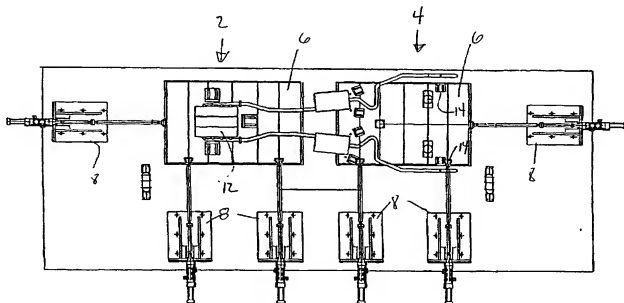
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

— With international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: DUAL MAST SYSTEM FOR SIMULATION TESTING



(57) Abstract: A simulation testing system and method for testing an automobile system or component(s) such as an exhaust system (14) comprises first and second multi-axis simulation tables. One part of the exhaust system is supported by one of the tables with another part being supported by the other table. Each table includes hydraulic actuators (8) capable of imparting motion to the tables in a number of directions. The tables are independent from each other so that the motion imparted to one table can be distinct and separately controlled from that motion imparted to the other table. By arranging the tables so that the motions can vary between the two tables, more realistic simulation testing can be performed on the system or component being tested.

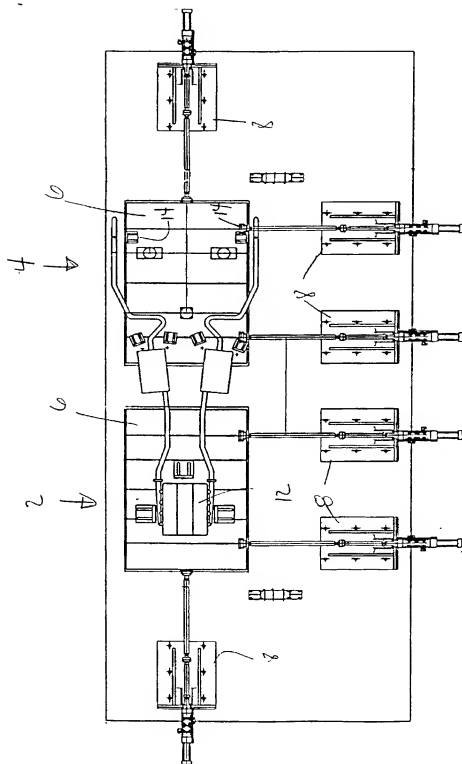
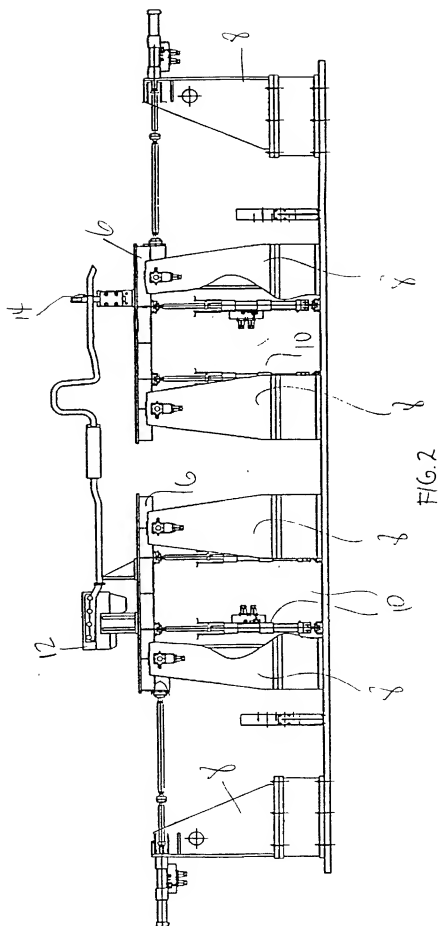


FIG 1



DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I declare that:

My residence, post office address, and citizenship are as stated below next to my name. I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter that is claimed and for which a patent is sought on the invention entitled

DUAL MAST SYSTEM FOR SIMULATION TESTING

☐ the specification of which is attached hereto.

☒ was filed on August 23, 2000 as International patent application no. PCT/US00/20790.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information of which I am aware and which is material to the examination of the patent application in accordance with 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b) of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT International application which designates at least one country other than the United States, listed below and have also identified below, by checking the space, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is not claimed.

Prior Foreign Application(s)

Number	Country	Day/Month/Year Filed	Priority Not Claimed
_____	_____	_____	_____
_____	_____	_____	_____

I hereby claim the benefit under 35 U.S.C. §119(e) of any United States provisional application(s) listed below.

Application Serial Number	Filing Date
<u>60/150,532</u>	<u>August 25, 1999</u>

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or §365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose information known to me which is material to the patentability as defined in 37 CFR §1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

Application Serial Number	Filing Date	Status (patented, pending, abandoned)
_____	_____	_____

Each undersigned applicant hereby appoints **CONRAD J. CLARK (Registration No. 30,340)** and **CHRISTOPHER W. BRODY (Registration No. 33,613)**, as his attorneys with full power of substitution to prosecute the subject application and to transact all business in the Patent and Trademark Office connected therewith.

Send Correspondence to: **CLARK & BRODY, 1750 K Street, NW, Suite 600, Washington, DC 20006; Telephone: 202-435-1111; Facsimile: 202-435-1755.**

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole or first inventor: Xuegang Zhu
 Inventor's signature: *Zhu Xuegang* Date: Feb. 11, 2002
 Residence: Toledo, Ohio
 Citizenship: P. R. of China
 Post Office Address: 543 Matzinger Road, Toledo, Ohio 43612, United States of America

Full name of second joint inventor, if any: _____
 Inventor's signature: _____ Date: _____
 Residence: _____
 Citizenship: _____
 Post Office Address: _____

Full name of third joint inventor, if any: _____
 Inventor's signature: _____ Date: _____
 Residence: _____
 Citizenship: _____
 Post Office Address: _____